DOE/NASA CONTRACTOR REPORT

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# DEVELOPMENT OF PROTOTYPE AIR/LIQUID SOLAR COLLECTOR SUBSYSTEM (Quarterly Report)


Prepared by

Owens-Illinois
Post Office Box 1035
Toledo, Ohio 43666



Under Contract NAS8-32259 with

National Aeronautics and Space Administration
George C. Marshall Space Flight Center, Alabama 35812

For the U. S. Department of Energy




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15. SUPPLEMENTARY NOTES

This work was done under the technical management of Mr. John Caudle, George C. Marshall Space Flight Center, Alabama.

16. ABSTRACT

This quarterly report covers the progress made in the development of the SEC-601 collector subsystem by Owens-Illinois under NASA/MSFC Contract NAS8-32259. The reports describes the installation and layout design, and parts fabrication. The master development schedule for the design of the system is also included.

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Summary. The principal activities during the reporting period included the fabrication, receipt and physical inspection of the tool try out unit of the Model SEC-601 collector, the construction of test fixtures for the physical testing of the collector and the initiation of documentation for the IPC detail verification test procedure. One subsection (2.6) was completed and submitted to MSFC. In addition, the 144 tube ERDA collector testing was continued in conjuction with the air/liquid heat exchanger and liquid storage element. Also, the Quality Assurance Plan was completed and submitted.

Technical Performance.

A. General description of work accomplished during the reporting period.

1. Installation and layout design, parts fabrication.

The first or tool try out unit of the collector was received in early December, 1977, on schedule. The Module was assembled with no interface problems experienced; viz., the form and fit functions were satisfied. The manifold was then sectioned for detail physical inspection and the construction of test units such as those required for outdoor exposure tests and hail resistance tests. It was determined that the assembly process of the manifold was inadequate and that severe air leakage from the manifold was experienced. One of the principal problems was the sealant material (MS-1002) used for caulking and sealing all of joints in the manifold. An inadequate amount of material was used and the sealant is air cured. The cure cycle was not completed where air penetration was retarded and inadequate bonding was observed. A high temperature silicone sealant, catalytically activated, was selected and sample bonds were tested in a 450°F air stream for in excess of 60 hours. Good bonding was demonstrated and the material retained the desired flexibility (rubberlike characteristics) following such exposure.

The partially completed No. 2 and No. 3 manifolds were returned to the Development Center so that the sealant could be applied under controlled conditions. The process was completed in January and the manifolds are scheduled to be shipped to the foaming vendor by February 2. The second and third manifold assemblies are expected to be completed by February 6, 1978. The extreme weather conditions experienced contributed to the delay in the program. Testing of the units the week of February 6, 1978, will determine program schedules towards the completion of contract requirements.

2. Prototype Design Review.

The revised Model SEC-601 collector design was submitted to MSFC in November, 1977. The physical inspection of the tool try out unit will result in minor changes in design and material specifications to reflect the modifications encorporated in the fabrication of the No. 2 and No. 3 units.

3. Verfication Tests.

The revised Verification Test Plan and the Detail Test Procedures were submitted to MSFC in November, 1977. Acceptance of the Plan and Procedures has been indicated informally with the condition that the sensible heat paramater be eliminated from the collector characteristic equation. This was acceptable to O. I. Section 2.6 of the IPC was completed be review and analysis. The documentation was formally submitted to MSFC as a test case for procedures to be used in the completion of certification of the remaining sections of the I.P. C.

The load test fixture was completed. This will be used for structural load tests and cyclical load tests. Air bags will be used for the application of the loads. Completion of the construction of the components for outdoor exposure, hail resistance, and vibration tests was interrupted pending the selection of a suitable sealant and acceptable assembly procudures. Verification testing is expected to be initiated in early February, 1978, approximately one month behind schedule. The severe weather conditions existing in Ohio will also likely delay the initiation of outdoor performance testing. All factors will be reviewed and a revised test schedule issued in February, 1978.

4. Air Collector Performance and Operational Testing.

The final report of the thermal performance and operational testing of the 144 tube ERDA air collector was issued in December, 1977. The closed cycle test loop encorporating the air liquid heat exchanger was operational in December and January. The data acquisition system continued to malfunction and was sent back to the supplier for repair. The data read out section was operational and two good days of performance data were analized by manual procedures. Certain preliminary judgements of significance can be drawn.

The effectiveness of the simple air/liquid heat exchanger is too low at a value of less than 30%. However, the pressure drop in the air side of the exchanger is very low. Baffling is being added to modify the air flow path towards attaining a significant increase in the heat exchanger effectiveness.

The data indicates a significant heat loss in the air side of the loop. The pressure at the inlet to the air fan is somewhat less than minus one inch of water. It is believed that this is causing an injection of cold ambient air of the order of 10% (5.6% calculated) into the air circulation loop. Air leakage is likely occuring in the manifold at the cups used to retain the sealing "O" rings in a small number of tubes. This causes a dumping of high temperature air to ambient. The minimal leakage expected in the Model SEC-601 collector manifold is expected to correct the problem. Time, cost, and severe weather conditions preclude corrective actions in the present system.

The analysis of data suggests that air mass flow was overstated by a few percent in reporting the performance of the 144 tube ERDA air collector. The air flow sensing element was located in the inlet duct to the array. The collector performance derived by the analysis of the closed loop test data is probably understated since the air flow sensing element was relocated to the collector air return duct. The weather conditions were clear and relatively warm on December 16, 1977. The collector elements were free from snow and frost. The backing screen was partially snow covered. The daily efficiency was .423 and the $\Delta\bar{T}/\bar{I}_{Tp}$ was .57. This operating point is above the contact specification but below the previously reported characteristic curve for the ERDA air collector. January 22, 1978, was clear and cold with a wind chill factor well below zero. The collector was almost 50% snow covered and all exposed glass surfaces covered with heavy frost. The backing surface was entirely snow covered. The daily efficiency was .31 and the $\Delta\bar{T}/\bar{I}_{Tp}$ was .7. This point falls right on the contract performance specification curve. It is apparent that the collector performance remains high even under severe snow and frost conditions.

A 350 gallon tank filled with 265 gallons of water is used for thermal storage. An analysis of heat loss overnight indicates a factor of 16 BTU/Hr.°F. This converts to a $U_L$ of .19 BTU/Hr. Ft.$^2$°F. A two inch fiber glass blanket was used to insulate the storage tank. Another two inch blanket will be added towards reducing the storage tank heat loss to a more acceptable valve. The heat loss in the lines between the /tank/pump and heat exchanger appears to be negligable.

An Eppley PSP pyronometer was used to sense the total radiation value. A recent model of an Eppley 8-48 pyronometer was calibrated by Desert Sunshine Exposure Testing, Inc. A second Eppley 8-48 pyronometer had been

used as the radiation sensor during the previous testing and analysis of the 144 tube ERDA air collector. All three units were tested side by side during a relatively clear and cloudless day. It was found that both of the Model 8-48 sensors appear to yield readings approximately 10% lower in value compared to the PSP pyronometer. It is not clear why there is such a discrepancy between the PSP and the calibrated 8-48 unit. This will be subject to further investigation. The collector performance values, reported above, were based on the PSP sensed values and reflect the impact of the higher apparent radiation levels.

All sensors and the data acquisition signal conditioning elements were recalibrated in November. The temperature sensors in the air and liquid loops were evaluated under steady state temperature conditions and found to track one to the other within ± .5°F. The liquid flow meter was calibrated by mass flow measurements for five minute increments for flow rates of 10.5 to 15 pounds per minute (approximately 1.25 to 2.0 times the air $\bar{m}c_p$ value at design air flow). Agreement to within ± .5% between indicated and measured liquid flow values was demonstrated. Water temperatures of 55°F and 140°F were investigated in the calibration of the turbine flow meter.

The collector test loop operating characteristics are considered to be fully investigated and understood. Conversion to the Model SEC-601 collector can be accomplished as soon as the unit is available and weather permitting.

5. Installation, Operation and Maintenance Manual.
Revisions to the preliminary drafts of those manuals were held pending the availability of actual hardware.

6. Quality Assurance Plan.
The Quality Assurance Plan was transmitted to MSFC on January 18, 1978.

B. Forecast of Activities to Complete Tasks.

1. The completion of fabrication of the No. 2 and No. 3 test units of the Model SEC-601 collector is now anticipated by early February, 1978. Structural and thermal cycling tests will be initiated upon receipt of the hardware.

2. The installation of unit No. 3 for thermal performance testing will be expedited. However, unusually severe weather conditions, not predicted in the forecasting of current schedules, could introduce unanticipated delays.

3. All activities will be rescheduled during February

when the necessary hard facts of hardware availability and the results of early on shake down tests are known.

4. The air-liquid test loop operation will continue to be operated with the ERDA collector array until the conversion to the Model SEC-601 collector can be accomplished. Emphasis of testing will be on the evaluation of changes to the air side of the heat exchanger towards an improvement in its effectiveness. Also, the effect of changing the degree of insulation around the liquid storage tank will be investigated.

5. The rewriting of the drafts of the Installation, Operation, and Maintenance Manuals will be initiated.

C. Identification of Major Problems Areas or Difficulties.

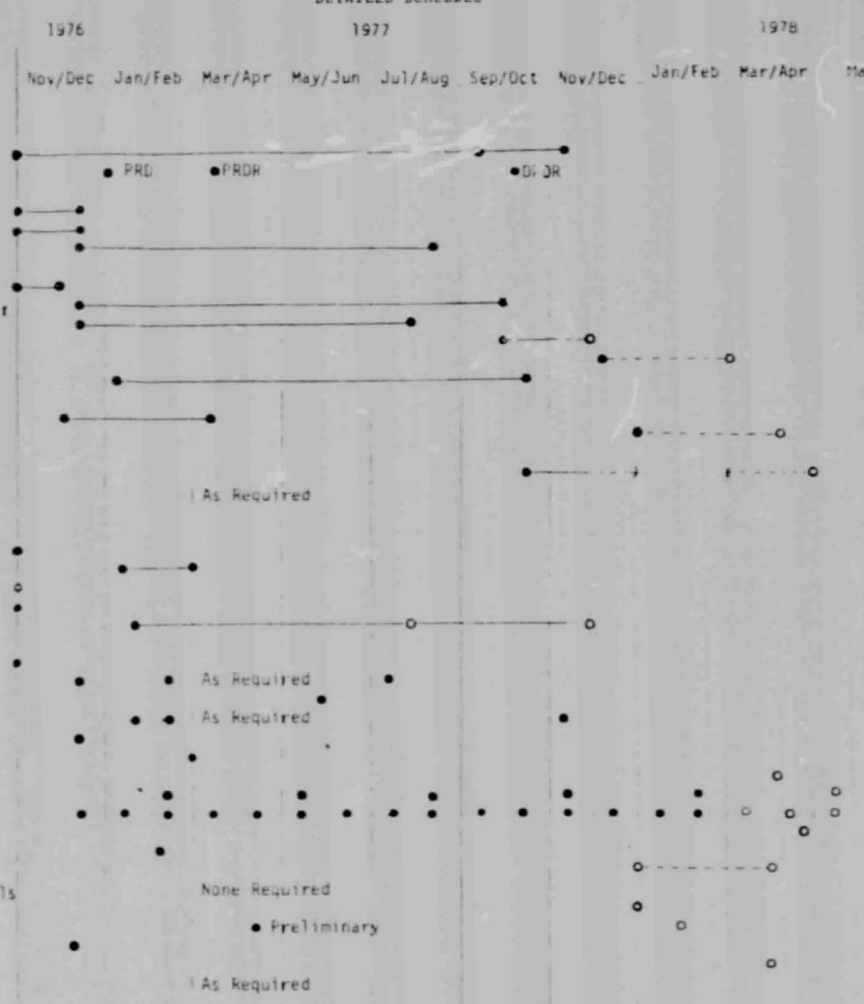
1. The attainment of the leak tight manifold has proven to be a major problem. Test coupon evaluation of the sealants selected at flowing air tests up to 450°F continuous for in excess of 60 hours have been promising. The results of the completed manifolds during February will be critical relative to the status of the overall program.

2. Unforeseen severe weather during late December and January has impacted schedules because of plant shutdowns and travel between vendors. The time will be difficult to recover due to the already tight schedule forecast in November, 1977.

D. Data Submittals

| Reference | Description |
|---|---|
| 259-47 | Proposed Verification and Test Prod. Change |
| 259-49 | Revised Baseline Drawings |
| 259-50 | October Status Report |
| 259-51 | Fourth Quarterly Status Report |
| 259-52 | 1st, 2nd and 3rd Revised Quarterly Reports |
| 259-53 | Progress as of 9/30/77 |
| 259-54 | November Status Report |
| 259-55 | Correlation Between Detailed Schedule & Budget |
| 259-56 | Interim New Technology Report |
| 259-57 | Qual. Test & Anal. Report-IPC 2.6 |
| 259-59 | Quality Assurance Plan |

DETAILED SCHEDULE




| | % Complete | Phase Number |
|---|---|---|
| 4.0 Contract Tasks | | |
| 4.1 Development Plan | | |
| Task 1-Design 72 Tube Module SEC-601 Collector | 100 | .001 |
| Design Review | | |
| Task 2-Build 4 Module Array ERDA collector | 100 | .002 |
| Installation Design | 100 | |
| Instrumentation Specification | 100 | |
| Procurement | | |
| Installation | 100 | |
| Site Preparation | 100 | |
| Installation | 100 | |
| Task 3-Thermal Performance Tests on ERDA Collector | 80 | .002 |
| Task 4-Operation Tests on ERDA Collector | 5 | .003 |
| 4.1.2 Interim Performance Criteria Tests (SEC-601) | 100 | .001 |
| 4.1.3 Packaging | | |
| 4.2 Certification | 100 | .003 |
| Review of Test Procedures | 5 | .003 |
| Review of Test Data, Analysis & Documents | | |
| 4.3 Manufacturing | 52 | .004 |
| 4.3.1 Fabrication | | |
| 4.4 Documentation Evaluation Data | | |
| 4.5 Management and Documentation | | |
| 505-2 Verification Plan | 100 | .005 |
| Preliminary | 100 | |
| Complete | | |
| 505-3 Quality Assurance Plan | 100 | |
| Preliminary | 100 | |
| Final | | |
| 505-4 System Performance Specification | 100 | |
| Preliminary | 100 | |
| Update | 100 | |
| 505-5 Source Control Drawings & Specifications | | |
| 505-6 Change Proposal | | |
| 505-7 Preliminary Design Review Data | 100 | |
| 505-8 Prototype Design Review Data | 100 | |
| 505-9 First Article Review Data | 0 | |
| 505-10 Quarterly Report | 83 | |
| 505-11 Monthly Status Report | 83 | |
| 505-12 Acceptance Data Package | 0 | |
| 505-13 Qualification and Acceptance Test Procedures | 95 | |
| 505-14 Qualification/Analysis Report | 0 | |
| 505-15 Special Handling/Installation/Maintenance Tools | | |
| 505-16 Spare Parts List | 0 | |
| 505-17 Installation/Operation/Maintenance Manuals | 50 | |
| 505-18 System Hazard Analysis | 100 | |
| 505-19 Design Data Brochure | 0 | .005 |
| 505-20 Non Conformance Report | | |

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